PROJECT FINAL REPORT

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4.1 Final publishable summary report

Executive summary

Most developed countries are confronted with a rising rate of obesity mainly due to bad eating habits, in particular, of not-well-balanced diet containing fat and low-size sugars. In many European countries, an excessive consumption of salt (almost 10 g a day) is also a problem as it is at the origin of cardiovascular risks and hypertension. Previous studies across countries with high incidences of strokes and cardiovascular diseases have estimated that around 850,000 lives could be saved every year if people reduced their salt intake to 5 g a day. As far as salt is concerned, bakery, meat, dairy and ready-to-eat foods are the main vectors for sodium intake and represent in industrial countries around 50% of the salt consumption while the use of the salt cellar contribute to 10-20% of the total salt consumption. Fat comes from different food sources such as butter, milk products, including cheese, meat products, spreading fats and oils and cakes varying according to countries. Together these sources also accounted for three quarters of the intake of saturated fatty acids, 58% of unsaturated fatty acids and 62% of trans fatty acids. Concerning sugar, cakes and confectionery products including chocolate are the main vector for sugar consumption in most European countries. In products such as sweet bread and cakes, the high glycemic index has potential for raising blood glucose levels, and is a dietary feature which may negatively influence metabolic and cardiovascular risk factors in the long term. A significant reduction of these ingredients in food will contribute both to saving lives and to reducing healthcare costs. However, the multi-functional roles of fat, sugar and salt in food has qualitative and quantitative implications for their composition. Consequently, changes in concentration or by substitution will affect many properties of the food such as texture, flavour perception, acceptability, shelf life, safety and nutritional properties.

In this context, the overall objective of TeRiFiQ is to achieve significant binary reductions in sodium-fat and fat-sugar contents of the most frequently consumed food products around Europe whilst at the same time ensuring the products' nutritional and sensorial qualities, safety and affordability for both industry and consumers so as to ensure wide adoption of the project technology at European scale.

TeRiFiQ addresses the four major food categories targeted by the European Commission. Concerning dairy products, soft, medium and hard cheeses are studied with the objective of reducing the sodium content (up to 30%) and at the same time to improve the quality of the fat content; hard cheeses being more consumed in the south of Europe and soft cheeses in north. Cooked sausages are studied with an objective to reduce saturated fat and sodium up to 50% while dry fermented sausages with an objective of 30% salt and 60% fat reductions. For sweet bakery products, the objectives are to reduce both the sugar and fat contents by up to 25%, and for sauces in ready-to-eat meals: 20% salt and 30% fat reduction.

Concerning technological aspects, fat lowering is mainly achieved by acting on its dispersion in food using multiple emulsions (meat products, bakery products, sauces). Tests of fat quality improvement are done by partially substituting with fat containing more poly-unsaturated fatty acids. For sugar, only natural sweeteners are tested as external substituent but taste enhancement by aroma perception may be used in reformulated products. New product formulations are tested for consumer acceptance in order to optimise them from a sensorial point of view then, for the most promising reformulated food products the applicability of the developed technologies are transferred at industrial scale for demonstration step.

Beside these technological developments, more basic knowledge on relationships between temporal flavour release, temporal perception information and food matrix composition and to

what extent cross modal sensory interactions are able to enhance taste perception allows to better understand the observed sensory phenomenon when the food is reformulated and to use this new knowledge to reformulate food better, without loss of acceptability.

Summary description of project context and objectives.

Most developed countries are confronted with a rising rate of diseases such as obesity, cardiovascular risks and hypertension, diabetes, cancers due to bad eating habits, not-well-balanced diet, in particular excessive consumption of salt, fat (saturated fat) and low-size sugars. Important healthcare costs could be reduces and lives could be saved over the world if people significantly reduced their salt, fat and sugar intake in their everyday food diet, even if the direct relationship between the ingredient and the health impact seems not so clear, because probably of the multifactorial origin of some diseases. Dairy, bakery, meat, and ready-to-eat foods are important vectors for sodium, fat and sugar intake and are targeted by the recommendations of public health organizations to reduce their content in foods.
These nutrients are often key ingredients of food products and an integral part of their structure, flavour perception and nutritional quality. In several cases, they are linked to multiple functionalities of the food and influence texture, flavour and mouthfeel characteristics which have a large influence in terms of food acceptability and therefore of consumers product preferences. Consequently, changes in concentration or by substitution will affect many properties of the food such as texture, flavour perception, acceptability, shelf life, safety and nutritional properties.
Thus, reduction in salt/fat/sugar therefore has to ensure maintained sensory properties and acceptability if the food industry is to adopt 'healthier' product formulation without economic loss.
In this context, the overall objective of TeRiFiQ was to achieve significant binary reductions in sodium-fat and fat-sugar contents of the most frequently consumed food products around Europe whilst at the same time ensuring the products' nutritional and sensorial qualities, safety and affordability for both industry and consumers so as to ensure wide adoption of the project technology at European scale. These binary reductions were done in different ways according to the food products, such as by fine-tuning current product formulations by engineering the technological parameters of realistic food models specific to each product and by applying state of the art technologies such as multiple emulsions in a manner never done before. In parallel to these technological developments, sensorial analyses were carried out to ensure consumer acceptability of these re-engineered foods.

The **WP1** was dedicated to the optimisation of cheeses with low salt and low saturated fat contents. In a nutritional point of view also, the possibility of salt reduction in cheese must be understood firstly as a technological optimization. Cheese being a fermented product, the first role of salt (NaCl) in cheese is to regulate and control the fermentations. For example, the main fermentations control variables in cheese are: starter strains, inoculation levels, temperatures, cheese moisture and salt (NaCl). As a consequence, the salt-level optimization was firstly studied in relation to fermentations for three cheese-types (soft, semi-hard, hard cheeses) as fermentations control ripening process (lipolysis, proteolysis, lactates fermentations, opening etc.) lead to the different aspect of final quality (texture, functionalities, taste, aroma). Then, the consequences of salt-optimisation on maturation processes on cheese quality were studied and corrections of the consequences of salt-level modifications on quality were done using different technological means. Finally, the unsaturated fatty acids content in cheeses was improved using particular sources of milk fat.

In processed meat products such as cooked and dry fermented sausages – **WP2** -, salt provides two further important functions; i) increasing microbial safety and extending shelf life, and ii) improving functional properties such as texture, water binding, and cohesiveness. Simply reducing the salt content in meat products has a negative impact on these sensorial, processing and microbial factors.
Alternatives to salt in processed meat products, such as partial replacement of sodium with other mineral salts, phosphates, flavour enhancers, enzymatic treatments and the use of water and protein binding additives cannot avoid the negative impacts on microbiology, sensory and functional qualities. The main objective of this workpackage was to develop cooked sausages and two dry fermented meat products: dry sausages (fuets) and chorizo with lower contents in sodium and fat using different strategies adapted for each products. Different strategies were examined in combination such as use of multiple emulsions, use of lean meat to decrease fat content, and use of prerigor meat, additives, optimisation of the technological conditions, predrying of raw meat materiel to reduce water activity (in the case of dry meat products), addition of molecules. Macro-, microstructure, safety, sensory properties and acceptability were evaluated after optimisation of the process of reformulated products. Moreover, a large focus was done on the impact on formation of flavour.

The objective of workpackage – **WP3** – was to reduce fat and sugar content in bakery products where they are both structural ingredients. Two types of cakes were studied: muffins and madeleines for which the technologies are slightly different. The explored strategy was mainly focused on the combined use of double emulsion, polymers such as inulin and polydextrose, use of natural and high potential sweeteners and aromas associated to sugar. A particular focus was done on the use of double emulsion which is a promising but as yet little used technology to reduce the fat content of bakery products. In this technology, the main drawback to overcome is the stability of the double emulsions. Water-in-oil-in-water emulsions (w/o/w) are susceptible to breakdown during processing and storage. Thus, there was a need for developments in formulation and manufacturing practice before multiple emulsions can become an applicable ingredient in bakery products in terms of structural, textural and sensory properties. The approach was to develop model bakery products with reduced fat and sugar contents taking into account the stability and functionality aspects in particular by controls at the microscopic level and rheological measurements, then to optimize the formulations and to ensure their good nutritional, safety, sensory properties and acceptance by the consumers.

The primary aim of - **WP4** - was to reduce the fat content of sauces used in ready meals by the use of multiple emulsions. Where possible, sodium and sugar reduction strategies were investigated using different strategies such as the use of aromas, spices, and natural sweeteners. A pizza sauce (high fat, high salt, low sugar) and a sweet cream (high fat, low salt, high sugar) were investigated for reformulation. Their generic construction is similar so far that they usually comprise emulsified fats or oils in a viscoelastic matrix, and containing tastants and odourants. The potential of multiple emulsions to significantly reduce the fat content in sauces was high because only a little effect was already observed on the sensorial properties which could be optimised by the droplet size and interfacial structure of emulsions. Model sauces (emulsions) were first developed with reduction in fat, sugar and salt contents and optimized in term of processing and storage. In particular, the structure and stability of the multiple emulsions were investigated by controlling their rheological properties and their particle size and structure by optical and electronic microscopy. After incorporation of the reformulated emulsions in more realistic sauces, the good quality of the products was controlled in terms of sensory properties, safety and acceptability.

A transversal and more scientific workpackage - **WP5** – was dedicated to the development of knowledge on mechanisms controlling in-mouth perception processes and cross-modal perceptual interactions. Global perception and appreciation of a food during eating is mainly due to the in-mouth temporal process leading to flavour and mouthfeel perception. However, many interactions occur between stimuli and between a stimulus and food matrix components at different levels. Otherwise, the overall perception of flavour is considered as an integration at the cortical level of simultaneous but different sensory perceptions including taste, aroma, chemosensory, texture… perceptions. Thus, foods of different compositions developed in the previous WP were studied with different approaches to improve the understanding of the main mechanisms leading to perception and with the idea to potentially use the results in the development of innovative reformulation strategies. As cognitive approach, perceptual interactions were studied as a putative lever to compensate salt, sugar and/or fat reduction, mainly focusing on cross modal aroma-taste interactions but taking into account changes in food composition. Both temporal *in vivo* and *in vitro* approaches were developed using direct mass spectrometry/temporal dominance of sensations and a chewing simulator, respectively. Changes in the food matrix and sodium mobility were studied at the microscopic and molecular levels respectively.

The main challenge of the **WP6** was to transfer and demonstrate at industrial scale the applicability of the technologies developed at the laboratory scale in the industrial production process as well as consumption of reformulated products by consumer in real industrial situations. The most promising reformulated products in each food categories able to be studied at industrial scale were selected according both technological and sensorial criteria then each SME partner applied the reformulations obtained in the previous tasks at an industrial scale using and adapting processing existing lines. The quality of the industrial reformulated products was evaluated in term of acceptability by the consumer, overall quality and affordability. Moreover, the consumer behaviour facing the reformulated products was evaluated in real-life condition for both appreciation and willingness to pay when consuming at home. The new products were also compared to the non-reformulated products and commercial products in the same category in term of appreciation.
In order to also test the transferability of the reformulations to other products a ‘new’ product was included in the industrial demonstration. Reformulation of meat pâté was tested from the strategies developed for the cooked meat. .

In **WP7** – Dissemination – TeRiFiQ meets important industrial, societal and fundamental scientific issues. Thus, we paid a particular attention to technology transfer, dissemination and outreach. The fundamental results were disseminated via scientific publications and communication in congresses to the scientific community. TeRiFiQ fits fully with the European perspectives to develop food products for better human health and with important issues of the platform “Food for life”. The outcomes of TeRiFiQ were released as soon as possible to the different stakeholders (industry, and societal stakes) through different ways: meetings, internet website, infosheets as it concerns both nutrition and food supply. The main objective was to make the best for a rapid application of the results by the food industry to help them to develop affordable and appreciated healthy foods answering to fulfilling consumers’ expectations.

Description of the main S&T results/foregrounds

Introduction

The main significant results obtained during the four years of the project are presented below as 23 key-results. They are organized in four main groups corresponding to each food category treated in TeRiFiQ: cheeses, meat products (cooked and dry sausages), bakery products and sauces with both scientific issues and industrial implementations. The last key-result is dedicated to the consumer behavior towards the new reformulated foods developed in the project.

1 - Dairy products

Key Result 1: the influence of the salt reduction on the overall maturation process (lipolysis, proteolysis) of cheeses is rather limited

Research background and aims

Salting of cheese constitutes one main technological variable used to preserve cheese by controlling the successive fermentations performed by the lactic acid bacteria starters and then by the ripening microflora.

In Swiss-type cheeses, the fermentations occur in the cheese body and the salt is brought by brining, leading to a progressive migration of the salt within the cheeses. The impact of salt is different according to the bacterial species present in the Swiss-type cheese ecosystem and during ripening time. Brining occurs after the starter bacteria such as streptococci and lactobacilli have finished their growth, and salt goes on migrating within cheese body during and after the growth of the main ripening bacteria, i.e. propionibacteria, i.e. during warm room period. The salt can affect the survival of bacterial cells as well as the activity of the enzymes that are in direct contact with the cheese micro-environment. Therefore, the level of salt can affect both proteolysis and lipolysis which are the main biochemical events to obtain final cheese characteristics, in terms of texture and flavour development.

In soft and semi hard cheeses, salt has a higher influence on the surface flora that can be partly controlled by washing the curd and the cheeses during ripening of smear ripened cheeses.

Results and applications

This higher proteolysis was confirmed but the results obtained in commercial low salt (-30%) Trappist, experimental Emmental, Brie and Raclette showed that improvement is lower than foreseen.

On the contrary the lipolysis is higher in low salt (-30%) Brie cheese.

In experimental Emmental cheeses, the activity and specificity of the different *Lactobacillus helveticus* strains, having various content in proteinase activity (from 0 to 4 proteinases on the cell surface), were studied on two caseins, αs1- and β-caseins. Among the four proteinases only PrtH3 was active, the others having a proteinase activity 10 times lower or even no activity as it was the case for PrtH. A higher enzymatic activity was observed at pH 5.2 than at pH 7.5. The lowest activity was observed on αs1-casein. The electrophoretic peptide profiles of αs1-casein did not differ between both pH, while there was a difference in the peptide profiles of β-casein. This difference could be due to a various accessibility of the caseins by the CEPs, through conformational changes either of the CEPs or of the caseins.

When the two strains having the highest proteolytic activities *in vitro* were used as starter in Emmental cheeses, i.e. the strains CNRZ32 (four proteinases at the cell surface) and ITGLH77 (only PrtH3), the decrease in salt differentially changed the activity of the proteinases according the salt range used, the decrease in salt from 3 to 1.5 % had more influence on the proteolytic activity and on other cheese characteristics, including i) cultivability of starter strains and growth of propionibacteria, ii) global proteolysis indices which increased when salt content decreased, and iii) functionalities such as oiling off, flowability, extrusion and stretchability, which decreased with salt content. In contrast, the reduction by 50 % of salt content (from 1.5 to 0.75 %) did not induce any significant changes for all the characteristics followed. Regarding the lipolysis mainly exerted by the propionibacteria in Emmental cheeses, the salt directly impacted the cultivability of the strains decreasing *de facto* the production and release of the extracellular esterase in this type of cheese.

Significance and benefits

The slight improvement of proteolysis could be interesting for texture, in particular in low salt (30%) semi-hard cheese like Trappist or Raclette cheese. The level of improvement of proteolysis depends on the cheese type and the temperature of ripening.

The increase of lipolysis in Brie cheese must be observed in details. It could be a source of soapy or piquant undesirable aromas. The extent of this lipolysis increase must be measured for the different cheese-types.

References

Corresponding deliverables D1.1 & D1.2 (public)

Proteinases of *Lactobacillus helveticus* and their distinct capability to hydrolyze α_{s1}- and β-caseins at different NaCl concentrations by Valérie Gagnaire, Xavier Lecomte, Romain Richoux, Jean–René Kerjean, Anne Thierry; 1st International PLEASURE Conference "Salt-Sugar-Lipids Reduction"; 18-19/06/2014; La Rochelle, France

Proteinases of *Lactobacillus helveticus* and their distinct capability to hydrolyze α_{s1}- and β-caseins at different NaCl concentrations: from *in vitro* experiments to Swiss-type cheeses by Valérie Gagnaire, Xavier Lecomte, Nicolas Pinon, Romain Richoux, Lydie Aubert, Marine Nurdin, Jessica Warlouzel, Jean-René Kerjean, et Anne Thierry, (2014). Presented at 17th Word Congress of Food Science & Technology (IUFoST), Montréal, CAN (2014-08-17 - 2014-08-21).

Key Result 2: The salt reduction (-30%) does not modify the general sensory quality and acceptability of semi-hard cheese (Raclette and Trappist) and of soft cheese with moulds (Brie), but important defects are noticed in Brie and soft cheese with smear (Boû d'Fagne)

Research background and aims

In bibliography, the reduction of salt by 30% in cheese seems to be possible for cheddar cheese. The increase of lipolysis in low salt soft cheese with moulds is known as a bad flavour hazard.

The increase of a_w in low salt hard (Emmental) or semi-hard (Saint-Paulin, Gouda or Trappist) cheeses increases the butyric acid fermentation hazard, which is the main defects in cheese due to the fermentation of cheese lactates by *Clostridium tyrobutyricum*, which spores originate from silage, without any danger for human health.

Salt reduction is known to pose problems for soft cheese with smear.

The objective was to know if these data were confirmed.

Results and applications

Sensory analysis shows that cheese salt reduction by 30% is clearly perceived by the consumers. This perception is not negative in the case of non-traditional cheeses. If the cheese is presented as a traditional product (e.g. Trappist cheese) reduced in salt then the consumer prefers the traditional form. Consequences on texture, aromas and odour are slight. In Raclette and Trappist cheese the aroma and texture seem a little improved. In low salt Brie cheese we do not notice soapy or piquant flavour, even when the lipolysis is clearly higher than in the standard product.

In winter, we observed clearly a butyric acid fermentation in low salt Trappist cheese (>60 mg/100g of butyric acid) due to the insufficient repression of *Clostridium tyrobutyricum* fermentation in the cheese body during maturation, leading to bad taste, blowing and serious defects.

In Boû d'Fagne cheese, the salt reduction led to the presence of white moulds (*Penicilium camembertii*) which are an important defect for this type of cheese.

Significance and benefits

Generally, the lowering of salt content in cheeses leads to matured products acceptable by the consumers but, in some cases, the higher activity of water causes serious defects (butyric defect in hard cheeses, presence of moulds on soft cheeses with smear) which must be corrected by a modification of technological parameters. The butyric defect can be corrected by adding egg lysozyme to the milk, which is authorized but must be signalled on the packaging, or by using specific lactic starters producing butyric acid fermentation inhibitors. On the contrary we did not find any adequate solution to limit the presence of moulds on soft cheese with smear. All the possible solutions dramatically modified the identity of this cheese-type.

Generally, the 30% salt reduced cheeses are slightly different from the original cheese but remain very acceptable by the consumers.

The modification of activity of water in low salt cheese leads to a modification of biochemical progress but this modification is limited when the salt reduction is -30%. At this level the consequences on quality is concentrated on the probability of manufacturing incidents (e.g. butyric fermentation) and does not lead to a general and proportional reduction of cheese quality.

References

Corresponding deliverable: D1.3 (public)

Reduction of salt and fat improvement in cheeses by Jean–René Kerjean; 1st International PLEASURE Conference « Salt-Sugar-Lipids Reduction; 18-19/06/2014; La Rochelle, France

Key Result 3: The simultaneous reduction of salt and saturated fatty acids only lightly impact the sensory and technical properties of Brie cheese

Research background and aims

In the project Agilait (CNIEL-Actalia-ANR) we demonstrated that the increase by 20% of the percentage of Unsaturated Fatty Acids (UFA) in emmental cheese did not modified a lot the main qualities of this cheese. We were looking for the possible modifications in soft cheese coupled with salt reduction.

Results and applications
The low salt Brie cheese with improved fat (+8% UFA) has a good quality and is not different from the low salt Brie cheese.

Significance and benefits
We concluded that it is possible to make correct Brie-type cheese with low salt and modified fat composition. Generally, we can conclude that 30% salt reduction is possible with some specific precautions linked to the type of cheese.

References
Corresponding deliverable: D1.5 (public)
Reduction of salt and fat improvement in cheeses by Jean–René Kerjean; 1st International PLEASURE Conference "Salt-Sugar-Lipids Reduction"; 18-19/06/2014; La Rochelle, France

Key Result 4: Aroma as a potential lever to compensate for perception in low-salt and low-fat dairy products

Research background and aims: Flavour perception is a multimodal sensation involving olfactory, taste and trigeminal stimulations generated by food components. These perceptions can interact between them through perceptual interactions. Moreover, the flavour compounds can interact with the matrix components, leading to release and/or retention phenomenon. Thus, changes in fat and/or salt content in cheeses may induce changes in flavour release and perception. In low salt and fat cheeses, lower taste perception may be compensated by other perceptual modalities. The challenge is to evaluate in what extents it is possible to play on the phenomena described above to try to decrease fat, salt and sugar content in food without negative impact on perception and acceptability.

Results and applications: Model cheeses varying in fat and salt content, pH at renneting and aroma composition were tasted in order to evaluate the ability of fat and salt associated aromas (butter and sardine, respectively) to compensate for salt reduction and fat in low salt cheeses products. The modification of salt and fat content as well as pH value induced changes in texture perception**.** The sardine aroma significantly increased salty taste in all products except the one with the highest salt and fat contents and highest pH at renneting. The butter aroma reinforced the perception of fat content unevenly across products. The impact of composition and / or food matrix structure appears more complex on the perception of fat compared to salt. Increasing pH at renneting increased the products firmness and decreased the level or aroma-induced fat perception enhancement, except for the cheeses with a high salt and fat content.
Concerning real cheeses, a semi hard cheese (Trappist, Orval) with 2 salt levels: a low salt cheese (-30%) and a regular salt cheese was tested. These cheeses were grated then flavoured by adding 1% of sardine aroma solution into lower salt cheese, of a 1% of butter aroma solution or of a blended aroma (1.3% of sardine aroma and 0.8% of butter aroma). A significant enhancement of saltiness intensity was induced by sardine aroma and butter aroma but the later in a lower extent while a limited effect was observed with the blended aroma. A significant fat perception enhancement was induced by blended aroma while butter aroma alone has no significant effect on fat perception and sardine aroma alone has a significant masking effect on fat perception.

In addition, product composition and structure (fat, salt and pH at renneting) also influenced aroma release (*in vitro* approach using a chewing simulator), which however depends on the nature of the aroma: the more hydrophobic compounds are less sensitive to variations in fat content and more sensitive to variations in pH and therefore to the products structure. The salt release kinetic during *in vitro* chewing was also influenced by the composition and structure of the products. Indeed, beyond salt content which determined the amount of salt released, fat content and the pH at renneting modulated the salt release kinetic.

Significance and benefits: These findings confirmed that the use of aromas can be an efficient strategy to compensate the reduction of fat and salt content in dairy products. However, the products' composition and structure influenced flavour perception and especially odour-induced perception enhancement but these effects appeared to be complex.
Thus, aroma addition alone or in combination with other strategies can assist the food industry when reformulating low-sodium and low-fat foods while maintaining consumer acceptability.

Prospect and challenges: to generate flavour compounds associated with saltiness and/or fat perception during the maturation of cheeses and to keep them acceptable for the consumers.

References:
Corresponding deliverables: D5.1, D5.2, D5.3 & D5.5
Syarifuddin A., Septier C., Salles C. and Thomas-Danguin T. (2016) Reducing salt and fat while maintaining taste: An approach on a model food system, *Food Quality and preference*. **48**, 59-69.
Syarifuddin A., Septier C., Salles C. and Thomas-Danguin T. (2016) Counterbalancing salt reduction with aroma and effect on sensory acceptability: a study with real cheese, in preparation.
Mosca A.C., Andriot I., Guichard E., Salles C. (2015) Binding of Na^+ ions to proteins: Effect on taste perception, Food Hydrocolloids, **51**, 33-40.
Syarifuddin A., Thomas-Danguin T., Septier C., Salles C. (2014) Reducing salt and fat while maintaining taste: An approach using cross-modal sensory compensation, SenseAsia 2014: The Asian Sensory and Consumer Research Symposium. Singapore.

Key Result 5: Industrial implementation of the reformulated cheeses

Background and aims
We observed defects in Trappist (semi hard cheese) and Boû d'Fagne (soft cheese with smear) and wished to correct them.
The question of purchase intent of consumers was answered before marketing low salt Trappist cheese.

Results and applications
Adding lysozyme from white egg is the main way to struggle against butyric acid fermentation linked to *Clostridium tyrobutyricum* in low salt Trappist cheese. This modification seems to be necessary and allows Orval cheese factory to market low salt Trappist.
The consumers' purchase intent is lower (-10%) for low salt Trappist, even if the flavour is not modified. This could be linked to the traditional image of this product, generally made in abbeys.

A lot of technological modifications were studied in order to improve the quality of low salt Boû d'Fagne cheese without any satisfying results.

Significance and benefits

These results show that the salt reduction must be studied cheese type by cheese type. In some case (Soft cheese with smear) the possibility of salt reduction seemed not practicable.

Prospect and challenges

The salt reduced cheeses are present on the market. Generally the reduction is -25 or 30%. It is a good market opportunity for cheese industry.

References

Corresponding deliverables: D1.4 and D6.1 (public)

Less sodium content and better fat in cheeses by Jean-René Kerjean; TeRiFiQ Final Conference; 27/10/2015, Milan, Italy

2 - Meat products

Key Result 6: Influence of salt and fat reduction on structure and physicochemical properties of cooked sausages

Research background and aims

The formulation of cooked sausages comprises lean muscle, salt, fat and binders. The technological function of salt in mainly to improve protein and water binding. It affects macro and micro structure of the sausages and influences the processing and the sensorial characteristics of the product. The objective is to explore strategies to reduce fat and salt content in cooked sausages

Results and applications

Emulsion done with sunflower oil was tested as fat replacer in cooked sausages. The microstructure of such emulsion was different from the same emulsion done with pork leaf fat. Emulsions with sunflower oil were better emulsified than emulsions with pork leaf fat; however an off-taste is detected. Thus the use of lean meat, low in fat, is preferable to decrease fat content more than 12% but is more costly. Concerning salt, by only optimizing the cooling step in salted solution immersion, the salt content can be reduced from the current 2.1% to 1.6% without major texture changes.

An experimental design where the nature of the meat (pork or beef), fat and salt contents, and presalting step varied allowed to better understand the impact of meat raw material and presalting on yield and texture using microscopy and different spectroscopic techniques such as NMR and FTIR. It was reported that meat raw material has a significant effect on both cooking loss and texture (beef vs. pork) as well as emulsion quality (lean vs. fatty). The mixture containing beef shows a water population with more restricted mobility than samples based on pork. By decreasing salt content in batter cooking, loss increases when total salt content is less than 2%. An increasing of salt concentrations induces an increasing level of β-sheets in protein structure in meat batters, which is favourable for water and protein binding properties.

Pre-rigor meat has better binding properties than post-rigor meat due to the increased pH level. Pre-rigor meat can be used directly for batter production, or the meat can be salted before the meat enters the state of rigor in order to maintain the high pH and thus the improved binding properties. Investigations on cooked sausages showed that pH was consistently approximately 0.2 units higher for the pre-rigor compared to the post-rigor series. This shows the efficiency of the pre-rigor trimmings in regulating the rigor development to higher binding ability, despite the short time available for adding salt. The measured texture was much firmer for the pre-rigor than post-rigor coarse sausages. This was confirmed by a sensory panel. Cooking losses were low for all series and not different between sausage types.

Significance and benefits

Reducing the salt content in meat batters leads to increased cooking loss and softer texture. Meat raw material with a low fat content gave rise to better emulsified batters compared to more fatty meats. Protein structure changes in meat batters of different salt concentrations, leading to changes in the quality of the products. The use of pre-rigor trimmings with high binding is a promising method to compensate for the reduced binding in low salt sausages.

References

Corresponding deliverables: D2.1 & D2.2

Hva gjøres for å få mer og bedre norsk kjøtt? (What is done to get more and better Norwegian meat?) by NOFIMA, Project presentation to representatives from the Norwegian food industry, 06/02/2014.

Key Result 7: Influence of salt and fat reduction on sensory properties and acceptance of cooked sausages

Research background and aims

Salt has a technological function by improve binding of water to meat proteins and thereby the viscosity of the batter during production. In the final product it will also influence texture, and of course saltiness when consumed. Similarly, amount and type of fat selected in the recipe will also effect processing and sensory perception.

Technically, there is no problem to reduce sodium and fat by 50%. However, to do it without changing textural and sensory perception of the product is a big challenge. The objective of this key-result is to report the effect of reformulation of cooked sausages on their sensorial quality and consumer acceptance.

Results and applications

The liking of sausages with a combined 20% salt reduction and 24% reduction of fat was similar to a standard sausage, provided that no information was given to the responders. When information about the content in the sausages is given to consumers the liking of the reformulated sausages is significantly reduced.

The sensory evaluation of sausages designed with different combinations of salt and fat reductions and sodium partially replaced by potassium compared to a reference sausage showed that this one was clearly different from the reformulated sausages which were evaluated as almost identical. The main differences were related to texture and saltiness. However, it is possible to reduce these differences by minor adjustments in the commercial recipe. This shows that samples with relatively large variation in sodium and fat content could be similarly perceived.

Significance and benefits

It is possible to reduce total salt content in cooked sausages by 20% and 20 - 30% of sodium can be partially substituted by potassium. Thus, sodium and fat contents can be reduced by 40% and by 20%, respectively, when compared with the reference product without significantly affecting the sensory properties of cooked sausages.

References

Corresponding deliverables: D2.2 & D2.4

Less fat and sodium in sausages by Rune Rødbotten, TeRiFiQ Final Conference, 27/10/2015, Milan, Italy

Key Result 8: Industrial implementation of the reformulated cooked meat products

Background and aims

The main objective was to implement and transfer knowledge obtained during laboratory tests into the production process of cooked sausages to improve the nutritional quality of the products.

In this way, Leiv Vidar and Nofima in collaboration, have optimized the recipe and process for frankfurters cooked sausages with the objective to reach 50% reduction in both fat and sodium content.

Hot-boned pork and different types of emulsifiers were tested in small-scale production. The tested emulsifiers giving off-flavour in the sensory evaluation of the sausages, they were not used in the industrial test production. That means that finally sodium and fat were the two factors only which were tested in full-scale production.

Results and applications

Sausages from five different nutritionally improved recipes were made at Leiv Vidar's plant with a total salt content lower in these batches compared with Leiv Vidar's reference sausage. In addition, some of the sodium was replaced with potassium and three recipes had less fat than the reference.

For the cooked sausages it was found that potassium could be a good substitute for sodium, and it is possible to exchange 20-30% of the sodium without influencing the sensory properties. Total fat content can be decreased, but a 50% reduction could be difficult without influencing texture and flavour.

Significance and benefits

- 20 to 30% of sodium can be substituted by potassium without affecting the sensory properties.
- It is possible to reduce total salt content to 1.8%, of which NaCl is 1.2% and KCl is 0.6%. This means sodium content is reduced by 40% relatively, when compared with the reference product.
- Sodium content can be decreased without significant change in sensory perception
- Fat content can be decreased without significant change in sensory perception

Prospect and challenges

Leiv Vidar will use these results for the fabrication and commercialization of new ranges of products with less salt and fat content for the nutritional benefit of consumers.

References

Corresponding deliverable: D6.2

Less fat and sodium in sausages by Rune Rødbotten, TeRiFiQ Final Conference, 27/10/2015, Milan, Italy

Key Result 9: Influence of salt and fat reductions on physical-chemical and biochemical properties of dry fermented sausages

Research background and aims

Salt and fat play key functional ingredients in dry-fermented sausage manufacture. Salt ensures microbiological safety by decreasing water activity (a_w), as well as acting on the drying process by decreasing weight losses. Salt also affects biochemical reactions such as proteolysis, lipolysis, oxidation and fermentation. On the other hand, fat in meat products is considered a valuable source of energy, fatty acids and vitamins. Several studies have focused on the effect of reducing salt or fat content on physical-chemical properties and biochemical reactions but, to our knowledge, few studies have addressed a combined reduction in salt and fat. Therefore, we aimed to quantify, from experimental designs, the effects of salt and fat contents and combined direct salt and fat reductions or partial substitutions of sodium chloride by potassium chloride and pork backfat by sunflower oil on the time-course of several key physical-chemical (product weight loss, mean a_w and pH values) and biochemical (proteolysis, lipolysis, lipid and protein oxidations) parameters.

Results and applications

Regarding combined direct fat and salt reductions, statistical analyses found that time, salt and fat contents had a very significant impact on weight loss and a_w and that time and salt content (not fat content) had a significant impact on pH. Biochemical results indicated that proteolysis was salt content-dependent and amplified by combined salt and fat reductions. Intensity of lipolysis was mainly dependent on fat content. Lipid and protein oxidations were more intense in higher-fat formulations. Combined salt and fat reductions in dry-fermented sausages thus increased acidification, weight losses and a_w, leading to more proteolysis, less lipolysis and less oxidation.

Regarding combined partial substitutions of animal fat and sodium chloride, in-depth statistical analysis revealed significant effects of time, animal fat and sunflower oil contents on product weight losses, and of time, animal fat and salt contents on a_w values. Proteolysis was strongly affected by time and salt content. Rate of lipolysis was mainly governed by animal fat and salt contents. As previously, lipid and protein oxidations were more intense in higher-fat formulations. Combining partial salt and fat substitutions thus led to globally acceptable water loss and a_w values and similar rates of proteolysis, lipolysis and lipid oxidation, but less protein oxidation.

Significance and benefits

The present results constitute a valuable set of data for helping professionals wishing to reduce salt and fat contents in dry-fermented sausages. We found that healthier dry sausages can be manufactured with no adverse effect on end-product physical-chemical and biochemical properties.

Prospect and challenges

Sensory studies are required to investigate final textural properties and consumer acceptability of these healthier sausages.

References

Corresponding deliverables: D2.1 & D2.3

Safa H., Gatellier P., Lebert A., Picgirard L., Mirade P.S. (2015). Effect of combined salt and animal fat reductions on physicochemical and biochemical changes during the manufacture of dry-fermented sausages. Food and Bioprocess Technology, 8, 2109-2122.

Safa H., Gatellier P., Berdagué J.L., Kondjoyan N., Mercier F., Favier R., Mirade P.S. Impact of flavouring and combined partial substitutions of sodium chloride and animal fat on physicochemical and biochemical parameters, texture and sensory attributes of dry-fermented sausage, in preparation.

Key Result 10: Influence of salt and fat reductions on flavour formation, sensory properties and acceptance of dry fermented sausages

Research background and aims

Salt affects proteolysis, lipolysis, oxidation and fermentation that are involved in the development of the final sensory attributes of dry-fermented sausages, such as texture, flavour and appearance. Other biochemical reactions affecting the lipid fraction are also involved in the development of the final sensory attributes of dry-fermented sausages, such as flavour, juiciness and texture. In literature, reducing salt and fat inputs in dry-fermented sausage manufacture reportedly leads to organoleptic and sensory defects and lower overall consumer

acceptability. Thus, we ran a comprehensive analysis of the odour-active compounds responsible for the characteristic intense aroma of high-quality dry-fermented sausages and the contribution of the flavouring to this aroma in order to identify simple technological levers to enhance the aroma of low-fat low-salt dry products. We also ran an in-depth experimental analysis to quantify how and to what extent flavouring (garlic, black pepper) and combined partial substitutions of sodium chloride by potassium chloride and pork backfat by sunflower oil affect the instrumental (product colour and texture), sensory characteristics and consumer acceptance of end-products designed to offer new healthier product formulations.

Results and applications

By analysing the volatile fraction of 5 artisanal dry-fermented sausages by gas chromatography–mass spectrometry coupled with olfactometry, we highlighted 34 different odour-active areas; 26 of them were formally identified. The structural identification and odour characteristics of these key aroma compounds made it possible to trace their most likely origins, demonstrating that flavouring (mainly garlic) contributed to about ⅓ of overall aromatic intensity.

In-depth analysis of seven purpose-manufactured formulations of dry-fermented sausages showed that sodium and animal fat contents can be drastically reduced with no adverse effect on colour, final textural properties or consumer acceptability. The role of flavouring proved very important, as it acted not only by adding aromatics (mainly garlic) that enhance aroma acceptability but also by activating fermentation processes (mainly black pepper) that further shape texture acceptability.

Significance and benefits

The interest of adding garlic was confirmed since this vegetable introduced aromatic notes that enhanced the dry-fermented sausages aroma. Adding garlic and black pepper is one possible solution that we can advocate to enhance the acceptability of low-fat low-sodium dry-fermented sausages.

Prospect and challenges

Flavouring, mainly with garlic and pepper, could therefore prove hugely valuable as a way to counterbalance the loss of aroma that occurs when manufacturing French low-salt and low-fat dry-fermented sausages. Various other flavouring solutions will probably have to be implemented to fit consumer tastes and eating habits in the countries or regions of retail in order to optimize the acceptability of new low-fat low-salt product formulations.

References

Corresponding deliverable: D2.3

Safa H., Gatellier P., Berdagué J.L., Kondjoyan N., Mercier F., Favier R., Mirade P.S. Impact of flavouring and combined partial substitutions of sodium chloride and animal fat on physicochemical and biochemical parameters, texture and sensory attributes of dry-fermented sausage, in preparation.

Safa H., Mercier F., Kondjoyan N., Mirade P.S., Berdagué J.L. Contribution of flavouring to key aroma compounds in dry-fermented sausage, in preparation.

Key Result 11: Flavour release and temporal perception in dry fermented sausages

Research background and aims

Fat and salt affect fatty-mouthfeel and saltiness of dry fermented sausages (DFS), respectively. Furthermore, both also contribute to the formation of aromas in DFS. Hence, the reduction or replacement of salt and the reduction of fat will affect taste, fatty mouthfeel and aroma of DFS. Literature shows that the opposite is also true: alteration of the aroma of a food can affect the perception of taste and fat-related mouthfeel. Hence, work in this work package aimed at:

1. clarifying effects of fat- and salt reduction and the use of salt replacer on the perceived quality of DFS.
2. clarifying effects of fat- and salt reduction and the use of salt replacer on the release dynamics of aroma components
3. identifying aromas that compensate for the reduction of fat and salt from DFS

Results and applications

The reduced saltiness, caused by lowering the sodium chloride content, was fully restored by replacing sodium with potassium. In fact, a 1:1 replacement of Na^+ by K^+ produced saltiness that exceeded the saltiness of the reference DFS. Aromas components characterised as 'salty' could not enhance the saltiness further, which is not surprising given the already high perceived level of saltiness.

Fat reduction did have a noticeable effect on the texture of DFS. Sausages were rated as less soft and more firm upon fat reduction. However, this change was not considered unpleasant. In fact, lower fat levels caused higher 'meaty flavour' scores, a positive change.

Addition of fatty-aromas did enhance fatty flavour of sausages, which was acceptable in low-fat sausages. However, the same flavour enhancement turned out to introduce rancid notes in the full-fat sausages. Hence, some fatty-flavour addition can be exploited in low-fat sausages only.

Significance and benefits

Perceptual evaluations of fat- and salt-reduced DFS indicated that the (partial) replacement of sodium by potassium produces a good alternative for regular DFS. It should be noted that a less-than full 1:1 replacement may be a better choice than a 1:1 replacement.

Given the successful salt replacement, an additional aroma-induced saltiness enhancement is not probable, even if alternative saltiness enhancing aroma formulations are considered.

The predominantly Dutch panel members indicated that the noticeable textural and aroma changes by fat reduction were positive. Hence, no efforts are needed to compensate for the lower fat percentage. However, consumers from other nationalities may have different opinions. If they would consider more firm sausages less pleasant, the principal route to more liked low-fat DFS would be to reduce the textural firmness. Compensation of aroma effects by fat-reduction was shown to be possible by adding volatile fat-oxidation products in moderate amounts.

Both the potassium salt and the fat reduction will enhance the price/kg. Given the improved health claim of the product, and the fact that there is no compromise on pleasantness, this cost increase should be accepted by the consumers.

References

Corresponding deliverables: D5.1, D5.3 & D5.5

Key Result 12: Industrial implementation of the reformulated dry meat products

Background and aims

TeRiFiQ objectives of binary salt and saturated fat reduction in dry sausages have been successfully achieved.

The main objective was to transfer and demonstrate at industrial scale the applicability of the technologies developed from WP2 in Boadas' industrial production process.

The development at industrial scale has been made only with snacks of fuet because the manufacturing technology is very similar to the chorizo one.

It was selected the best reformulated test using the following criteria:

- tested in pilot plant at lab scale in WP2 to ensure industrial feasibility,
- accepted at consumer level,
- tested and controlled in terms of nutritional quality and safety,
- acceptability regarding cost benefit analysis for each studied product.

Taking into account all these facts, ADIV and BOADAS have optimized two Spanish dry sausages: the chorizo extra and the snack fuet extra.

Results and applications

ADIV demonstrated at pilot scale that the use of fat emulsion and fibers was a good solution to reach the SFA reduction. For salt reduction, the cold predrying during 3 days associated with a 30% substitution of NaCl by KCl or addition of yeast extract associated with 40% salt substitution by KCl were efficient technologies.

Then, Boadas demonstrated at pilot plant that binary reduction in SFA and sodium can be achieved simultaneously.

- For snacks of fuet the better results in terms of texture and taste were with oil and fiber addition + modified KCl + flavor enhancer (yeast extract). 70% of SFA reduction and 35% of salt reduction has been obtained.
- For chorizo the better results in terms of texture and taste are with fat emulsion + modified KCl + natural flavouring. 60% of SFA reduction and 40% of sodium reduction can be obtained.

The sensorial evaluation of these reduced products (performed first by ADIV and Boadas and finally for expert judges and consumers) shows that new formulations are very close to the control and there aren't significant global differences with it.

Significance and benefits

- More than 70% reduction in saturated fatty acids (SFA) and more than 35% in sodium could be achieved,
- For snacks of fuet the best tests in terms of texture and taste are with sunflower oil with wheat fiber, modified KCl and flavor enhancer (yeast extract),
- Sensorial attributes are very close to control on every criteria. Characteristic taste of snacks of fuet is achieved,
- With the pre-dried process at low temperature we have efficient microbial results because the pH is lower than control,
- Yield of reduced test at industrial scale is a little bit lower than control (10%), however, it could be concluded that reduced products at industrial scale are affordable,
- The implementation of research activities in WP2 and WP6 leads to the demonstration that new strategies are efficient to reduce simultaneously the salt and saturated fatty acid contents in dry sausages, respectively by 35% and 70 %.

Prospect and challenges

TeRiFiQ results on dry sausages have provided real solutions to "meat companies" by offering healthier products for consumers and without losing the product authenticity.
Boadas has brought to the market 3 new products developed during TeRiFiQ project.
These new products are part of a new healthy range of products that Boadas 1880 wants to bring into the national and international markets. At this time Boadas has planned and agreed to begin selling the product in January in Auchan Italy and in Casino France. Boadas is preparing its presence in the most important trade fairs in Europe and America for the next two years: ANTAD Mexico, SIAL Canada, SIAL Paris to present these products. It will be prepared tastings, in different supermarkets, to approach the product to the end consumers.
Boadas aims now at expanding this new knowledge to another typical Spanish product: the Serrano Ham.

References

Corresponding deliverable: D6.2
Reduction of fat and sodium in cooked and dry-fermented sausages (poster), TeRiFiQ Final Conference, 27/10/2015, Milan Italy
Reduction of fat and sodium in dry-fermented sausages (flyer), TeRiFiQ Final Conference, 27/10/2015, Milan Italy
"Success stories by TeRiFiQ SMEs" (roundtable), TeRiFiQ Final Conference, 27/10/2015, Milan Italy

3 - Bakery products

Key Result 13: Effect of sugar and fat reduction on texture, physicochemical and sensory properties of muffins: Simultaneous reduction by 40% fat and 10% sugar is possible without consumers perceiving sensory differences (Health by stealth)

Research background and aims:

Muffins typically contain 15% to 25% fat and sugar on batter weight basis. The fat assists in the incorporation of air bubbles into the batter during mixing, helps to leaven the product, tenderizes the crumb, imparts moistness, and enhances mouthfeel. Sugar, on the contrary, is not only responsible for the sweet taste and Maillard browning, but also gives bulk and volume, increases the viscosity of the batter, facilitates air incorporation, and increases the protein and starch gelatinization temperature by restricting water uptake by proteins and starch. In order to reduce fat and sugar in muffins successfully, the functionality of the ingredients needs to be replaced, so that texture, physicochemical and sensory properties are maintained. The aims were to determine the influence of fat and sugar reduction on the texture, physicochemical and sensory properties of muffin formulations and to quantify the fat and sugar reduction levels that can be achieved without consumers perceiving sensory differences between fat and sugar reduced muffins and full-fat, full-sugar muffins.

Results and applications:

A series of baking trials indicated that sugar and fat impart important functional properties to the muffin batter as well as the baked muffin. Especially sugar seems to have a more pronounced effect on the quality attributes of muffins than fat. The main consequence of reducing sugar is a lower viscosity of the batter, which leads to less air retention, thus lower aeration of the crumb. Concurrently, the more sugar is reduced, the more water is available which lowers the protein denaturation and starch gelatinization temperature. These two

structural changes lead to an increased hardness and chewiness of the muffin. As the lipid source in the model muffins was sunflower oil, it does not assist in the incorporation of air bubbles into the batter during mixing. However, it seems that considerable fat reductions do not have strong influences on textural properties. Discrimination sensory tests were executed with naïve consumers to determine the fat and sugar reduction levels that can be achieved without consumers perceiving differences in sensory properties.

Significance and benefits:
40% fat or 15% sugar reductions are possible in model muffins without consumers perceiving sensory differences relative to full oil or full sugar muffins. Simultaneous reduction by 40% fat and 10% sugar is possible without consumers perceiving differences relative to full sugar/fat muffin. This demonstrates that a reduction of sugar and fat content in muffins can be achieved while maintaining sensory properties of muffins. Further simultaneous fat and sugar reductions might be achieved when the reduction steps are gradual and small and spread over months/years so that consumers do not notice changes in the formulation (Health by stealth).

References:
Corresponding deliverable: D3.1
Strategies to reduce sugar and fat in muffins: reduction by stealth, addition of fibers and aromas; Conference: Food Matters Live Event, 18-20/11/2014, London Excel Centre, UK

Key Result 14: Effect of gelation of inner dispersed phase on stability of ($w_1/o/w_2$) multiple emulsions and Descriptive sensory profiling of double emulsions with gelled and non-gelled inner water phase.

Research background and aims:
The use of water-in-oil-in-water ($w_1/o/w_2$) multiple emulsions offers potentially a method for the reduction of oil in foods. The issue with multiple emulsions is that they can have stability problems during food processing, where the w_1 droplets escape from the oil droplet, so the level of fat reduction that is reached is reduced. Therefore, first we investigated methods for the preparation of stable multiple emulsions. We studied the influence of osmotic pressure tailoring and gelation of the inner dispersed w_1 water droplets on the stability and yield of multiple emulsions. Yield is defined as the percentage of water retained in the inner dispersed phase w_1 after preparation, storage, heat or shear treatment. Secondly, we investigated the sensory perception of double emulsions by descriptive sensory profiling using a trained panel. Two sets of emulsions with either 30% or 50 % dispersed phase fraction were studied. Each set differed in composition (gelled and non-gelled inner w_1 phase, gelatine as gelling agent) and fat reduction level, but was similar in oil droplet size and viscosity. Fat reduction level depended on the amount of water droplets entrapped inside the oil droplets.

Results and applications:
Gelation of the inner aqueous phase w_1 by gelatine or whey protein isolate increased stability and yield of multiple emulsions after preparation, storage (after 7 days at 20°C), shear (5 min at 10,000 rpm) and heat treatment (30 min at 97°C) by 20% to 50% compared to reference emulsions. Yield and emulsion stability were correlated to oil droplet sizes and the mechanical properties of the gelled inner dispersed droplets. Yield increased with increasing fracture stress and modulus of gelled w_1 droplets. The multiple emulsions were evaluated on nine sensory attributes describing taste, mouth-feel and after-feel perception, including thickness, creaminess, fattiness, and cohesiveness. The replacement of oil by small water

droplets w_1 did not decrease the intensity of the sensory perception of fat-related attributes. When inner w_1 droplets were gelled, 47% oil could be replaced in the multiple emulsion while even increasing the intensity of fat-related sensory attributes. This indicates that the sensory perception of single and multiple emulsions with gelled and non-gelled w_1 phase is mainly determined by the total oil droplet surface area. The composition of the inner water phase (gelled or not) also influences the sensory perception of double emulsions.

Significance and benefits:
Stable food-grade multiple ($w_1/o/w_2$) emulsions can be prepared by gelling the inner dispersed phase. These multiple emulsions are able to withstand shear and heat treatments. Fat reduction up to 47% can be achieved in multiple emulsions while maintaining or even enhancing the sensory perception of fat-related attributes such as thickness, creaminess and fattiness. This provides opportunities to use multiple emulsions as potential fat replacers in foods.

References:
Corresponding deliverables: D3.1 and D3.2
Oppermann, A.K.L.; Renssen, M.; Schuch, A.; Stieger, M.; Scholten, E. (**2015**) Effect of gelation of inner dispersed phase and osmotic pressure on storage, shear and heat stability of (w1/o/w2) multiple emulsions. Food Hydrocolloids (48) 17-26.
Oppermann, A.K.L.; Piqueras-Fiszman, B.; de Graaf, C.; Scholten, E.; Stieger, M. (**submitted**) Descriptive sensory profiling of double emulsions with gelled and non-gelled inner water phase. Food Research International.

Key Result 15: Single and multiple emulsions as fat replacers in muffins: Reduction of oil content in muffins by up to 58% using w/o emulsions is possible without consumers perceiving sensory differences

Research background and aims:
Multiple emulsions are a promising strategy to reduce oil content in food products such as muffins. We previously investigated the increase in storage, heat and shear stability of multiple emulsions by gelling the inner water phase and osmotic pressure tailoring as well as the sensory perception of multiple emulsions. Previously, we found that oil content in muffins can be reduced by 40% without replacing those 40% by a fat replacer. Consumers did not perceive a difference in sensory properties between the 40% fat reduced muffin compared to a full fat muffin. Therefore, we studied whether oil content in muffins can be reduced even further than 40% by using single emulsions or multiple emulsions as fat reduction strategies.

Results and applications:
Single o/w emulsions and multiple emulsions with different oil reduction levels (different amounts of gelled and non-gelled inner water phase) were applied into muffins and the sensory properties of the fat-reduced muffins determined. Probably due to high sugar concentrations in the outer water phase, an osmotic gradient between the inner water phase and outer water phase was created, which led to diffusion of inner water droplets to the continuous phase. It seems that no water was entrapped as w_1 in the oil phase of the multiple emulsions anymore. Muffins containing multiple emulsions were perceived significantly different from the full-fat reference muffins in sensory discrimination test with naïve consumers and did not allow to reduce oil content in muffins further than 40%. Muffins containing single water-in-oil emulsions with a fat reduction level of up to 58% were not perceived significantly different from full-fat muffins.

Significance and benefits:
Oil content in muffins can be reduced by up to 58% using w/o emulsions without significantly changing the sensory properties compared to full-fat muffins. These fat reduction levels in muffins were not achieved using multiple emulsions.

References:
Corresponding deliverable: D3.2
Optimized Formulations of Fat and Sugar Reduced Muffins and Madeleines (poster); TeRiFiQ Final Conference; 27/10/2015, Milan Italy
Less fat and sugar in muffins and madeleines by Markus Stieger, TeRiFiQ Final Conference; 27/10/2015, Milan Italy

Key Result 16: Industrial implementation: Production of sugar and fat reduced muffins using inulin: Simultaneous reduction by 25% sugar and 25% fat is possible while maintaining product quality

Research background and aims:
The aim was to upscale the production of nutritionally improved (fat and sugar reduced) muffins to industrial production scale, evaluate the nutritional quality and determine sensory performance and consumer acceptance. Inulin was used as fat and sugar replacement for the muffins in order to achieve the target, which was a simultaneous reduction by 25% fat and 25% sugar. Inulin is a carbohydrate widely occurring in chicory roots which is composed of a mixture of linear chains of fructose units. Inulin is of low caloric value and consider a low caloric bulking agent and dietary fibre which delivers up to 50% of the sweetness compared to sucrose.

Results and applications:
The nutritionally improved muffins contained an increased amount of carbohydrates, but less sugar. The addition of inulin more than doubled the fibre content of the nutritionally improved muffin compared with the reference muffin. The sensory properties of the nutritionally improved muffins were determined using Quantitative Descriptive Analysis by a trained panel on 23 attributes. For plain muffins, no significant differences between the reference muffin and fat and sugar reduced muffins were observed. For muffins prepared with pieces of milk chocolate, small but significant differences between the milk chocolate reference muffin and fat and sugar reduced milk chocolate muffins were found for the attributes juiciness, vanilla odour and sour flavour. The differences found by the trained subjects were too small to be perceived by naïve consumers. A discrimination test clearly demonstrated that naïve consumers could not perceive a sensory difference between nutritionally improved muffins (reduced by 25% fat, 25% sugar and added inulin) and full-fat, full-sugar reference muffins. These findings were further confirmed by a field and lab study combining sensory evaluation and experimental economy. Consumers evaluated liking, pricing and sensory perception of the muffins in comparison with other brands. The nutritionally improved muffins (reduced by 25% fat, 25% sugar and added inulin) successfully maintained consumer appreciation and were at least as acceptable as full-fat, full-sugar reference muffins.

Significance and benefits:
Simultaneous reductions of 25% fat and 25% sugar in plain muffins and milk chocolate muffins were achieved using inulin as fat and sugar replacer while maintaining sensory

properties and consumer acceptance compared to full-fat, full-sugar muffins. Only small technical adjustments were needed in the up-scaled muffin production process to optimize product quality.

References:
Corresponding deliverable: D3.3
Optimized Formulations of Fat and Sugar Reduced Muffins and Madeleines (poster); TeRiFiQ Final Conference; 27/10/2015, Milan Italy
Less fat and sugar in muffins and madeleines by Markus Stieger, TeRiFiQ Final Conference; 27/10/2015, Milan Italy

Key Result 17: Industrial implementation: Reformulated Madeleines

Research background and aims:
Madeleine is a traditional sponge cake with a long shelf-life. The aim was to reduce fat and sugar content in Madeleines by 25% each. Rapeseed oil is commonly used for the industrial production of Madeleines. The reduction of fat and sugar content in Madeleines without compensation leads to a lack of coloration, poor rising of the dough during baking and higher water activity in the product which increases the risk of microbial spoilage.

Results and applications:
Several methodologies to reduce fat and sugar in Madeleines while maintaining product quality were investigated. Recipes were optimized using a water activity prediction software since water activity is a critical parameter in the risk of moulds growth. Different types of inulin and/or polydextrose were studied. The yield, texture properties of dough and product, colour, volume, water content and mould growth risk during shelf-life were determined. Generally, good results were obtained, but the texture of the reformulated Madeleines were firmer than the full-fat, full sugar reference Madeleines. The differences in texture properties were also perceived by a sensory panel. An increased loss of water during storage was observed for the reformulated Madeleines. Furthermore, waxy starch was used to prepare fat and sugar reduced Madeleines. The rising properties of the dough were good and the texture properties during storage were also improved. Trials using multiple emulsions as a fat replacer in Madeleines were not successful due to a lack of dough rising and aeration of the crumb. An enhancement of sweetness perception of sugar reduced Madeleines was achieved by the addition of specific aroma compounds.

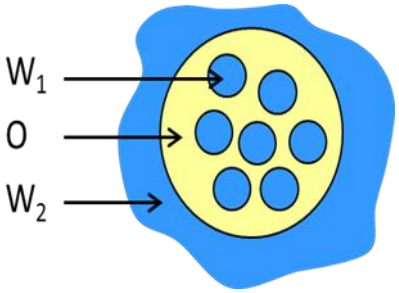
Significance and benefits:
Technical adjustments in the production process of reformulated, fat and sugar reduced Madeleines are needed to optimize product quality. A combination of reformulation strategies allows to develop nutritionally improved Madeleines.

References:
Corresponding deliverable: D3.3
Optimized Formulations of Fat and Sugar Reduced Muffins and Madeleines (poster); TeRiFiQ Final Conference; 27/10/2015, Milan Italy
Less fat and sugar in muffins and madeleines by Markus Stieger, TeRiFiQ Final Conference; 27/10/2015, Milan Italy

4 - Sauces

Key Result 18: Designing of stable double emulsions for food reformulation

Aims and Background:
The main aim of this WP is to develop strategies for reducing fat and salt/sugar in sauces for ready-prepared foods. The primary focus of this task was to develop formulations and protocols to create multiple water-in-oil-in-water (wow) emulsions that would work in conjunction with other salt and sugar reducing approaches. The sensory perception of fat content in emulsified foods depends on the number and size of emulsion droplets in order to impart a "creamy" mouthfeel. Replacing fat droplets with non-fat particles can impart a similar texture, but the mouthfeel and sensory perception of fat content is reduced due to the lack of fat. Our approach is to use multiple water in oil in water emulsions (WOW). Here, the oil droplets which form the emulsion, incorporate water droplets within them as shown here. The problem with multiple emulsions is that they can have stability problems during processing, where the W_1 droplets escape from the oil droplet, so the effect on fat reduction is lost. Therefore we studied a range of methods to obtain the most stable WOW emulsions for incorporation into real foods.



Results and Applications:
The most important factor for stabilising WOW emulsions is the choice of emulsifiers. Two emulsifiers are required, a hydrophobic emulsifier to stabilise the W_1 water droplets in oil during the first stage of the process where the aqueous phase (W_1) is emulsified into the oil phase (O) to create a water in oil (WO) emulsion. The stability of these water droplets was found to be critical. Many different hydrophobic emulsifiers and combinations were tested, but the only one which conferred sufficient stability to survive heating and shear during processing was polyglycerol polyricinoleate (PGPR). This emulsifier has a unique structure which is ideal for stabilising WO emulsions, and is permitted in a range of foods.

The next stage of production was to emulsify the WO emulsion into a second aqueous phase (W_2), containing a hydrophilic emulsifier to stabilise the oil droplets. The type of emulsifier here did not seem to be as important in general, and protein based emulsifiers seemed to confer good stability in general, and may even have helped to encapsulate the W_1 water droplets. Lecithin and sucrose stearate also showed good stability, but the sucrose stearate tended to form larger emulsion droplets. Various emulsifier combinations were subjected to a range of processing treatments including shear, temperature and osmotic stress. The table shows some results of thermal treatments on a selection of emulsifier combinations. Some proteins were sensitive to thermal processing above 150°C compared to lecithin based emulsifiers, so the lecithin became the preferred hydrophilic emulsifier if significant heat was used during processing. Similar effects

Heat Stability of WOW emulsions				
Emulsifier 1	Emulsifier 2	Heat Treatment		
		100°C (5m)	150°C (5m)	200°C (5m)
4% PGPR	2% WPI	Stable	Stable	Unstable
2% PGPR	2% WPI	Unstable	Unstable	Unstable
2% Span 80	2% WPI	Unstable	Unstable	Unstable
4% PGPR	2% lecithin	Stable	Stable	Stable
2% PGPR	2% lecithin	Stable	Stable	Stable
WPI : whey protein isolate				

were seen when exposing the WOW emulsions to high shear rates, although the proteins generally performed more effectively.

Significance and benefits: The outputs of this task provided a number of protocols that could be adapted for the preparation of multiple emulsions that were suitable for a range of foods and processing environments, not only for this WP but also for WP2 and WP3.

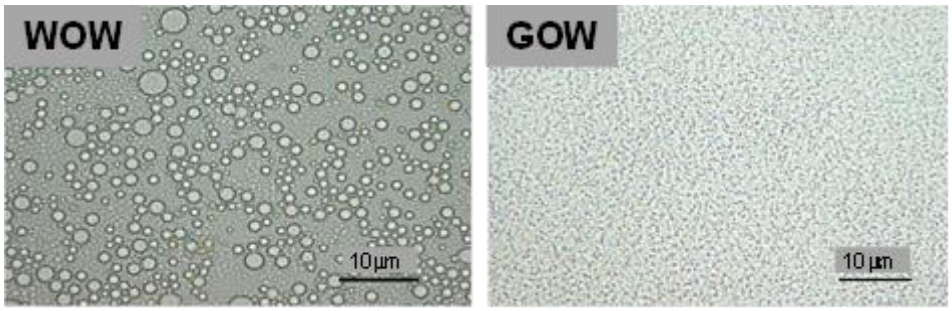
Prospect and challenges:
To maintain the stability of the WOW structure during processing of real foods. The use of PGPR is only regulated in certain foods.

References:
Corresponding deliverable: D4.1
Formation and stability of Multiple emulsions by Peter J. Wilde, 27/03/2014, TeRiFiQ Annual Meeting

Key Result 19: Use of double emulsion in combination or not with other reformulation strategies to lower salt, fat and sugar in sauces

Aims and Background:
The main aim of the project was to achieve binary reductions in fat, salt or sugar. The primary goal of this workpackage was to apply multiple emulsion technology to reduce the fat content in sauces. The key issue with WOW emulsions is stability, and the one associated with changes in salt and sugar is the stability to gradients in osmotic or chemical potential. This is because the salt / sugar content of the W_1 water droplets is fixed during homogenisation, but the osmotic potential of the outer W_2 aqueous phase may change during processing, particularly where in reduced salt or sugar formulations. Therefore methods were developed to improve the stability of WOW emulsions to osmotic / chemical stress, and the effect of salt and sugar replacers on the stability of these emulsions.

Results and Applications:
All of the WOW emulsions were found to be sensitive to osmotic stress, for example, the W_1 droplets would shrink and disappear if the salt or sugar concentration of the W_2 phase was higher than W_1. This would have a detrimental effect on the effectiveness of the fat reduction. Therefore methods were developed to improve the resistance of the W_1 droplets to osmotic stress. The best approach that we found was to transform the W_1 droplets into a gel, thus they would mechanically resist swelling or shrinkage under osmotic or chemical stress. Two approaches were developed which could be used in a range of foods. Firstly using an alginate based polymer, which requires the presence of calcium to form a gel. Here, a $CaCl_2$ solution was added to the emulsion during the first homogenisation stage, this allowed the gradual incorporation of calcium into the W_1 droplets, promoting gelation. The other method was to use a carrageenan based polymer which required heat to



gel, often, the heat generated during homogenisation was sufficient to promote gelation. In both methods, smaller W_1 droplets were produced (see figure on left), probably due to reduced recoalescence rates during emulsification. These emulsions were termed gel in oil in water (GOW) emulsions, and were generally more resistant to osmotic stress than WOW emulsions. The next stage was to determine whether replacing salt and sugar in model foods would have any impact on the stability of the GOW emulsions. Different salt replacement strategies were studied for a tomato sauce based product. These included yeast extract, micronized salt, modified potassium chloride and the addition of garlic flavour and herbs to enhance the saltiness perception, but these latter strategies were only appropriate for use in pizza sauce type products due to the negligible impact on the overall flavour of the product. Sugar replacement was required for a sweet cream topping type product. Here, a 15% reduction in sugar was achieved by replacing some of the sugar with a stevia extract. In both systems, no obvious effects on stability were observed. The viscosity of the tomato sauces remained constant for the duration of the shelf life of the product, suggesting no breakdown in structure.

Significance and benefits:
The outputs of this work provided preliminary protocols for the production of reformulated real food products (tomato sauce for pizza and sweet creams for cakes).

Prospect and challenges:
To maintain the stability of the GOW structure during processing of real foods and positive sensory attributes compared to the standard recipe

References:
Corresponding deliverables: D4.1 & D4.2

Perez-Moral N, Watt S, Wilde P J. (2014) Comparative study of the stability of multiple emulsions containing a gelled or aqueous internal phase *Food Hydrocolloids*. **42**, 215-222.

Key Result 20: Effect of reformulation on sensory properties and acceptability of sauces

Aims and background:
To develop pilot scale products reformulated for reduced fat, salt and sugar, based on GOW emulsions and determine the preliminary sensory acceptability of the reformulated products to help optimise the product at the industrial scale. GOW emulsion and micronised salt were used to reformulate the pizza sauces recipes achieving a 30% decrease in fat and a 20% decrease in salt content in the final products. GOW emulsion and sugar replacer (Stevia extract) were used to reformulate the sweet filling cream recipe achieving a 30% decrease in fat and a 30% decrease in sugar content in the final products.
The sensory evaluation was performed by trained assessors at Expergo Sensory Research, Romania. The sensory attributes to be used were agreed by all evaluators and were clearly defined during training sessions held before the effective test.

Results and applications:
The sensory panel compared the original and reformulated products and compared them against the agreed sensory attributes. The results demonstrated that although some differences were found, many were in favour of the reformulated products. The mean difference was below the significance threshold of +/- 2.0. Therefore there was no statistically significance difference detected between the original and reformulated products.

Significance and benefits: Some small differences were found, although they were no deemed to be significant, they were useful markers to help refine the reformulation of industrial scale products. The improvement in colour is likely to be due to the presence of the GOW emulsions that scattered light more strongly. The Stevia extract appeared to affect the flavour and sweetness of the creams, so the Stevia could in fact be reduced, and an increased dose of vanilla flavour was added. These results were taken forward for the development of whole foods in Task 4.4.

Prospect and challenges:
The initial sensory properties were very promising, and with some modification, the prospects for a good quality, healthier products look promising.

References:
Corresponding deliverable: D4.3
TeRiFiQ Project: Design of multiple emulsions to reduce fat in sauces and ready prepared foods by Natalia Perez-Moral, Monica Trif, Eva Csutak, Didier Pintori, Malte Bethke and Peter Wilde, 1st International PLEASURE Conference « Salt-Sugar-Lipids Reduction; 18-19/06/2014; La Rochelle, France

Key Result 21: Influence of emulsion structure and composition on fat and salty perception

Research background and aims:
The use of emulsions seems to be a promising way to reduce fat content in foods. The objective was to investigate whether the use of double emulsions is a feasible strategy to reduce fat content in food products. Due to the current need of decreasing the consumption of fat, there is an interest in reformulating food products without affecting their sensorial characteristics. In this context, single and double emulsions were compared in terms of mouth-coating, fat and salty perception. In particular, this study investigated whether the addition of salt in the inner water phase of double emulsions can influence both fatness and saltiness perception, and whether the addition of congruent aromas could be used to sensorially compensate for salt and fat reduction.

Results and applications:
Single (OW) and double emulsions (WOW) varying in composition were designed in order to evaluate the influence of their composition and structure on salt release, mouth-coating and, fat and salty perception. Two single emulsions varied in fat/water content (21/79 and 30/70) and three double emulsions made from the 30/70 single emulsion, contained 0, 4 and 8% salt in the inner water phase. No significant difference for mouth coating and salt release was observed according to the different emulsions, suggesting that salt in the inner phase is not released in the mouth. Concerning perception, neither fat content perception nor saltiness perception was significantly affected by any change in structure and composition of the emulsions. This suggests that 30% fat and salt content reduction can be done in emulsions without any detrimental effect on sensorial characteristics of the food.
The ability of fat and salt associated aromas (butter and sardine, respectively) to compensate for salt and fat reduction was tested in a single (OW 21/79) and the corresponding double (WOW) emulsion. The emulsion type did not influence saltiness perception. In addition, the aromatization of emulsions did not show a significant saltiness enhancement. Regarding fat

content perception, it was perceived with a higher intensity in the double emulsion compared to the single one but the aromatization of the emulsions did not seem to enhance fat content perception in emulsions, whatever their structure.
These findings indicate that the use of double emulsion seems more appropriate for fat reduction in foods by replacing fat by emulsions. However, in this case, the use of aromas to compensate for the reduction of fat and salt does not seem to be an efficient strategy in foods reformulated with emulsions, though the addition of aromas increased the aroma dimension of emulsions.

Significance and benefits:
Emulsions can be used by food industry to reduce fat content in foods. However, this strategy should be coupled with other strategies than the addition of aromas to compensate for salt and fat content perception in order to follows the recommendations by the public health organisations. In double emulsions, salt should be in the outer phase to impact saltiness perception.

References:
Corresponding deliverables: D5.3, D5.5
TeRiFiQ project: multiple gel in oil in water emulsions as fat replacers in sauces and ready prepared foods; Monica Trif, Eva Csutak, Natalia Perez-Moral, Tibor Gagyi, Didier Pintori, Malte Bethke and Peter J. Wilde; Bulletin of University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca. Food Science and Technology; 2016; 73(1)

Key Result 22: Industrial implementation of the reformulated sauces

Background and aims:
Following the rational development of reformulated products in previous tasks, full scale production of the pizza sauce and the sweet creams were implemented, and more extensive quality, safety, sensory and consumer tests were carried out. 60 participants took part in the consumer tests, held in the sensory laboratory of Department of Food Science and Technology from University of Agricultural Science and Veterinary Medicine Cluj-Napoca, Romania. Commercial food products were verified from a sensorial, chemical and microbiological point of view in laboratories of DSV (Local Sanitary, Veterinary and Food Safety Authority (ANSVSA)).

Results and applications:
The nutritional information of the different products was calculated (see Deliverable D4.4). Rigorous control procedures based on HACCP and Good Manufacturing Practice (GMP) ensured the safety of the food produced. This was verified by ANSVSA laboratory that all the foods were deemed safe according to the chemical and microbiological testing. Consumer groups, both in the university setting and at various events were asked to compare the standard and reformulated products. The reformulated products were found to be comparable in many aspects of their sensory and consumer acceptance tests (See Deliverable D4.4). The only significant difference was with the sweet creams, where the reformulated product was reported has having a slightly greater level of unpleasant aftertaste than the standard product.
Consumers were also asked about how much they were prepared to pay for a reformulated product, considering the health benefits that reducing the fat, salt and sugar could have. Those individuals with higher than average levels of education were prepared to pay up to 5% more for a healthier product. Whereas, those in the lower educational background were not prepared to pay any more for the reformulated product.

Significance and benefits:
Based on these results, it appears that consumers enjoyed the reformulated products, and some consumers would even be prepared to pay a little more, when considering the quality and health benefits.

Prospect and challenges:
Educating certain sectors of society as to the added health benefits of reducing salt, fat and sugar in foods may have an impact of the cost of manufacture, and ingredients and processes that enable the reduction may actually be more expensive, and although some consumers may be willing to pay a little more, others are not. The other challenge is the current limitation on the use of PGPR as an emulsifier. However, there is ongoing research looking at other methods to produce multiple emulsions using food ingredients, but the processing is more complex and expensive. Some manufacturers would be willing to use PGPR where permitted, but others were not.

References:
Corresponding deliverable: D4.4
Less fat, salt and sugar in sauces by Peter Wilde, TeRiFiQ Final Conference; 27/10/2015, Milan Italy

5 – Consumer behaviour

Key Result 23: Real life Consumer behaviour towards reformulated foods

Background and aims:
Most of sensory studies aiming to evaluate product appreciation and acceptance take place in lab denying the psychological influence of tasting food products in a very artificial environment. Therefore, and to be fully in line with the TeRiFiQ project whose objective is to consider these products in “everyday-life”, a focus was put on the ecological, psychological and economical aspect of the products evaluation, including both overall liking evaluation in real-life setting and willingness to pay experiments The aim is to evaluate the consumer behaviour facing the reformulated products with a lower content in sodium, fat and sugar in real-live condition.

Results and applications:
Consumers were given two packed lunches with two weeks interval. One contained reformulated foods developed in TeRiFiQ and the other one was prepared with the corresponding non-reformulated foods (Chorizo (Boadas), mini-fuets (Boadas), knacks (cooked sausages, Leiv Vidar), semi hard cheese (Trappist, Orval) and muffins (Millba). The packaging was not distinguishable between the two packed lunches. The consumers were instructed to taste these products in normal conditions of degustation (at home) and to rate first pleasantness and secondly to assess the price they are willing to pay. Then, they were instructed to re-evaluate the price regarding the real revealed price. Finally, in a session carried out in the laboratory, all the consumers were asked to rank for each food category the pleasantness of: the reformulated food, the non-reformulated one, a corresponding trademark brand and store brand.
Among the tested products, the reformulated chorizo and dry sausages were significantly more appreciated than the initial products. For the semi hard cheese and muffins, no

difference in appreciation was found between the reformulated and non-reformulated ones. Only the reformulated cooked sausages were considered as less appreciated than the non-reformulated ones. It seems that for cooked sausages, the lower appreciation was mainly due to texture.
Among the tested products, the willingness to pay was higher for the reformulated chorizo and dry sausages than for the non-reformulated ones. For the semi hard cheese, cooked sausages and muffins, no difference was found between the reformulated and non-reformulated ones. In all the cases, a rather good and positive correlation was reported between appreciation of the products by the consumers and the maximal price they are willing to pay. The willingness to pay before and after the consumers know the real price of the food were maintained for the Trappist cheese, chorizo, dry sausages and muffins though they try to adjust their willingness to pay to the real price. Only for the cooked sausages, the willingness to pay after knowing their real price increased significantly for the reformulated product compared to the non-reformulated one.
Concerning food product sorting, there was no difference between the reformulated and non-reformulated semi hard cheese and muffin. Moreover, they were ranked with a higher value than the commercial similar products. The reformulated chorizo and dry sausages were ranked with a higher value than the non-reformulated and with the same value as the store brand. The reformulated cooked sausages were ranked with a lower value than the non-reformulated, the store and the trademark brands. Surprisingly, in most of the cases, the trademark brand had the tendency to be ranked with a lower value than the store brand.

Significance and benefits:
For most of the products reformulated in the TeRiFiQ project, reformulation maintained consumer appreciation in real life conditions and for two of them reformulation not only maintained but improved the pleasantness. Moreover, in most of the cases, the reformulated and non-reformulated foods developed are at least as appreciated as the equivalent commercial products. For the most appreciated products, the consumers are willing to pay for what they feel as “quality” (until 12% more). This economic margin can be used by the industry for eventual additional costs due to the reformulation process.

References:
Corresponding deliverable: D6.5
Paper in preparation: Sébastien Romagny, Emilie Ginon, Christian Salles; Impact of reducing fat, salt and sugar in commercial products on the consumer eating behavior and willingness to pay. Food Quality and Preference.

Conclusion

TeRiFiQ showed that the binary reduction approach (sodium/fat and sugar/fat) was a relevant approach to reduce sodium, fat and sugar content in major categories of foods and the different strategies can be combined to compensate more efficiency for perception. There is no universal strategy but strategies should be adapted and fine-tuned in function of the kind of foods. In most of the cases the ambitious reduction targets were reached with a good acceptability of the reformulated product by the consumers. All the developed strategies can be relatively transposed at the industrial scale with sometime an additional cost due to the addition of steps in the food process line. The SMEs were highly involved and were able to develop new reformulated food products very competitive compared to existing food products

in the same category marketed in food shops. Several food products developed in TeRiFiQ are marketable or almost marketable as they are now, and some of them are already marketed; for example, ORVAL Trappist Cheese reduced in salt, BOADAS Spanish Chorizo slices or cubes and Mini Salames.

Potential impact and main dissemination activities

TeRiFiQ covered **nine EU countries** (Belgium, France, Germany, Italy, the Netherlands, Norway, Romania, Spain and UK) and **11 SMEs** were partners including nine SMEs which are food producers. This partnership gives a good opportunity for spreading both scientific and technological results over European countries.

The project has been promoted on **TeRiFiQ public website** (http://www.terifiq.eu) during the entire project, by the **French food cluster Vitagora** (website, newsletters), in different large public events such as International Agricultural Show and in meetings organized by different clusters for both industry and public organizations through oral presentations. The project aim and results were also presented at meetings of the European platform "diet, physical activity and health" of the DG SANTE.
The TeRiFiQ website provides information on the project structure, objectives and workplan, and on project results with links to published results and relevant conferences and workshops. Moreover, a TeRiFiQ project presentation was used at all times by all partners for every communication and dissemination activity at key sector events in order to enhance communication of the project by the different partners.

Two TeRiFiQ Newsletters were edited on the website and sent out to all project contacts (100 subscribers from outside the TeRiFiQ Consortium) informing of the project results, workshops and sector news. These newsletters mainly targeted SMEs, large industries and policy makers/consumer groups. They will remain available on the website in the future, after the end of the project.

Different partners summarized main research and demonstration results, at the end of the project, into an easy an readable forms which was collected by Federalimentare Servizi and formatted as **"infosheet"** then sent to all SPES third parties- except ANIA who received the translation by FEVIA (FEDERALIMENTARE, FEVIA, FIAB, FHFI, FFDI, CCIS CAFÉ, SETBIR, SEVT, FIAA and FIPA) to be translated from English in their national languages (i.e. Italian, French, Spanish, Hungarian, Czech, Slovenia, Turkish, Greek, German and Portuguese). The translated infosheets were sent to SPES contacts by e-mails reaching more than 20.000 contacts. Moreover, each SPES third parties (ANIA, FEDERALIMENTARE, FEVIA, FIAB, FHFI, FFDI, CCIS CAFÉ, SETBIR, SEVT, FIAB and FIPA) put a link within their institutional web site to TeRiFiQ web site thus reaching the 99% of European SMEs and use their channels to reach national and European policy makers: presentation of the project was made during ETP and NTP "Food for Life" meeting as well as during the SPES third parties institutional events.

The most important key-findings from the research and developments workpackages were translated in **Guidelines** (last deliverables) at the attention of food industry, SMEs in particular, to develop new foods with low sodium, sugar and fat contents:

- Guidelines for production process for nutritionally improved cooked sausages
- Guideline for production process for nutritionally improved dry fermented sausages
- Bakery product nutritional quality, sensory performance and acceptance
- Report on the industrial implementation of the reformulated cheese products and recommendations
- Report on the industrial implementation of the reformulated meat products and recommendations

- Report on the industrial implementation of the reformulated bakery products and recommendations
- Report on the industrial implementation of the reformulated sauces and recommendations
- Report on consumer behaviour in real-life conditions and recommendations for product pricing, marketing and labelling

The **Industrial Advisory Board** (IAB) constituted of large industry, clusters and a distributor gave advices during the entire project. They were invited to meet the consortium and to assist to the kick off meeting and all the annual meetings of the project. They participated to all the presentations of the more recent results, asked questions freely and discussed with all the partners. They were allowed to assist to all the sessions and give comments and advise for the following and orientations of the works. In addition, a specific IAB workshop was held at the middle of the third year of TeRiFiQ where project related results were released and discussed. IAB members who were present gave us a feed-back and advices. They were provided with all the documents related to this workshop. IAB activities at the same time served as a sound board for TeRiFiQ and assure that the needs of the targeted industries are taken on board throughout the project so as to ensure the relevance and transferability of the TeRiFiQ results.

The TeRiFiQ **dissemination tools** (Website, Newsletters, workshops and symposium) had a dedicated section for the different stakeholder groups (Industry, consumers, policy makers etc.) in order to inform the general public of the importance in health and nutrition terms of reducing their intake of fat/sugar/salt via their choice of products. All the public deliverables are available on the TeRiFiQ website. Eight press releases and several interviews for public media were done during the project and a workshop on salt reduction in dairy products was organized by ACTALIA (ACTIA). All these initiatives have assured a very large dissemination of TeRiFiQ findings over Europe.

At the end of the TeRiFiQ project, an **open symposium** was organised by Federalimentare Servizi at Milan EXPO. It was oriented towards all stakeholders (research community, food industry, consumer organisations). During this event, Food and Drink stakeholders including the TeRiFiQ Industrial Advisory Board, received the main project outcomes. A total of 74 persons attended the meeting. The morning was dedicated to the presentation of the main scientific results of the project while the afternoon was dedicated to the industry. In particular, the SMEs partners of TeRiFiQ were invited to present their own success story in TeRiFiQ and their projects concerning the new developed products and their future, and to discuss and answer the questions of the assembly. A round table was also organized with different industrial and public stakeholders: DG SANTE, FoodDrinkEurope, national consumer's association, ACTIA, large industry where discussion was held on food consumption, food reformulation, food industry, communication and consumer education. All the slides presented during this event remain available on the TeRiFiQ website.

From the beginning of the project, **eight peer reviewed articles** have been already published and more than 10 are in preparation. **127 oral communications and 15 posters** have been presented in different national or international meetings for industry and the scientific community.
A book is in preparation. It will mainly contain the results obtained in TeRiFiQ and Pleasure (the other EU FP7 project granted on the same topic) on the different approaches and strategies to develop foods with a lower content in sodium, fat and sugar. The targeted readers are students, teachers, academic institutes and industries.

TeRiFiQ has contributed to the **training of students** of different levels.

Three PhD students have been involved in TeRiFiQ (salary funded by TeRiFiQ directly or on other funds):

- Anika Oppermann (University of Wageningen, NL) was fully involved in the WP3 (bakery products) and will defend her PhD in 2017.
- Adiansyah Syarifuddin (University of Burgundy, FR) was fully involved in the WP5 (Flavour release, cross modal interactions) and defended his PhD on the 29th June 2015 at Dijon. He is now lecturer at the University of Hasanuddin, Indonesia)
- Hassan Safa (University of Clermont Ferrand, FR) was fully involved in the WP2 (dry sausages) and defended his PhD on the 25th January 2016. He is looking for a job now.

Three postdoctoral students were also involved in TeRiFiQ:

- Ana-Carolina Mosca was involved in the WP5 at CSGA INRA Dijon (FR). She is now in China for a 3-years contact.
- Sébastien Romagny was involved in the WP6 (demonstration) at CSGA INRA Dijon (FR). He is now looking for a job.
- Natalia Perez-Moral was involved in the WP4 (sauces) at IFR Norwich (UK).

Moreover, several master trainees were involved in TeRiFiQ at different steps of the project.

An important event for TeRiFiQ was our **participation to the final meeting of Pleasure** (the other FP7 project granted on the same topic) in June 2014 at La Rochelle (FR) where we had the opportunity to present a general overview of the objectives and several scientific results to a large community of stakeholders.

The biggest success of TeRiFiQ is that **several reformulated food products developed in the project are already marketed**: dry sausages and chorizo in French and Italian supermarkets and they will be more largely distributed in a near future, and Trappist cheese in the local shop of Orval Abbey in Belgium. Moreover, after the demonstration step, several other food products developed in TeRiFiQ are ready for launch onto the market, such as Muffins, cooked sausages, tomato sauces and sweet filling cream. Thus some SMEs are now in contact with the ProBio project (H2020) to go further for the development of new food products and their marketing.

Project public website
The website address is the following: http://www.terifiq.eu

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4.2 Use and dissemination of foreground

Filled in online reporting tool.

4.3 Report on societal implications

Filled in online reporting tool.